Exploration of a Magma-Sediment Hydrothermal System on Earth: Constraints on the Habitability Potential of Martian Noachian Hydrothermal Systems.

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Introduction: The martian crust is predominantly composed of basalt [1] and hosts a large variety of alteration materials caused by wide-ranging processes from volcanic hydrothermal processes to sedimentary and post-magmatic (e.g., see [2] and reference within). Specifically, there is an abundance of evidence that water previously flowed on Mars, ranging from ancient stream beds [3], lake basins [4], sedimentary fans in Jezero crater [5, 6], and clay minerals [7]. These secondary minerals have been observed by landers and rovers [2], from orbit [8], and in martian meteorites [9-11]. Along with low temperature alteration, high temperature hydrothermal systems from volcanic processes, as well as meteorite impacts, should have been present [12,13]. However, finding evidence of high-temperature hydrothermal activity has been challenging. To better understand these processes on Mars, Earth analogs can be used and then compared to potential scenarios and locations on Mars. Therefore, here we investigate a mafic dike and the surrounding metamorphic contact zone that has been hydrothermally altered from contact with ground water as it was emplaced. We will also compare our results to previous work on Robbers Roost Dike, an older mafic dike near our field location that intruded a similar protolith causing a potentially habitable hydrothermal system [14. 15].

Geologic Field Site: DC Dike (DCD) is located in the Colorado Plateau, in south-central Utah. Here, a mafic dike intruded on the Jurassic Entrada Sandstone, which is part of the San Rafael Group. The Entrada Sandstone is an iron silty sandstone deposited in an eolian to tidal environment [16]. The dike, part of the San Rafael volcanic field, is believed to be between 3.8 and 4.6 Ma [17]. DCD is a black dike intruding an earthy Entrada Sandstone that varies in color from red to tan. Throughout the dike, there were large xenolith sections of baked Entrada Sandstone (Fig. 1 A). Some of the xenolith sections had crystal pockets (Fig. 1 B).

Other dikes from this sill and dike swarm have been explored, including Robbers Roost Dike, which also intruded the Entrada Sandstone [14, 15].

Methods: Multiple rock samples were collected from DCD at six different locations. At our sampling location, the dike was exposed at the surface in an arch shape, with Entrada Sandstone in between the exposed mafic rock (Fig. 2). The first three samples were collected on the left part of the arch, with samples 67 and 69 being the altered contact rock and 68 a sample of the dike. The other three samples were from the thicker right side of the arch, with sample 70 being the altered contact rock, and 71 and 72 from the dike. Sample 71 had small xenolith pockets in the sample of mafic rock. Sample 72 was predominately the xenolith rock with some of the surrounding dike attached.

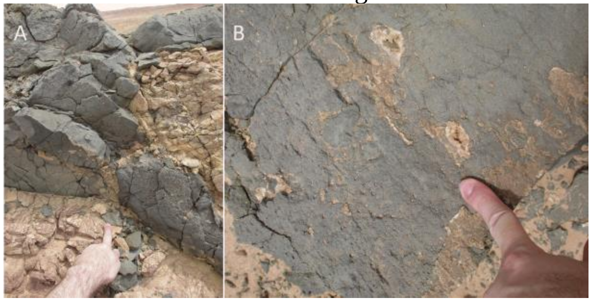

Figure 1. A: Picture of black mafic dike with red and tan baked Entrada Sandstone xenolith. B: Close up image of crystal pockets found in the DCD. Finger for scale in both images.

We have chosen Mars analog instrumentation to make our results direct applicable to those on Mars: Visible-Near Infrared reflectance spectroscopy and X-Ray Diffraction.

The 21 samples were analyzed with a TerraSpec 4 Hi-Res Visible-Near Infrared Spectrometer, with wavelengths from 350-2500 nm. Each location on the sample was analyzed twice to minimize movement errors. Every side of the sample was analyzed, as well as any spots that had variation in color or texture. Spectra are being analyzed using Spectral Geologist for mineralogy following previous procedures [14, 15].

Ongoing analyses for bulk mineralogy will be run by XRD at NASA Johnson Space Center.

Preliminary Results and Conclusions The VNIR spectral analyses for each location were averaged and the mean spectra per location was plotted against each other (Fig. 3). The locations of contact rock are depicted in shades of blue. The locations of mafic dike are depicted shades of pink, and the xenolith sample in purple. The first thing of note is the contact rocks share similar spectra, especially samples 67 and 69. The dike samples are also fairly similar. All 6 locations show strong dips at the water absorption bands, 1.4 and 1.9 nm.

Figure 2: Field site of DCD. Six samples were collected, with sample location seen above. 67, 69, and 70 are contact rock. 68 and 71 are from the dike, and 72 is xenolith crystals inside the right side of the dike.

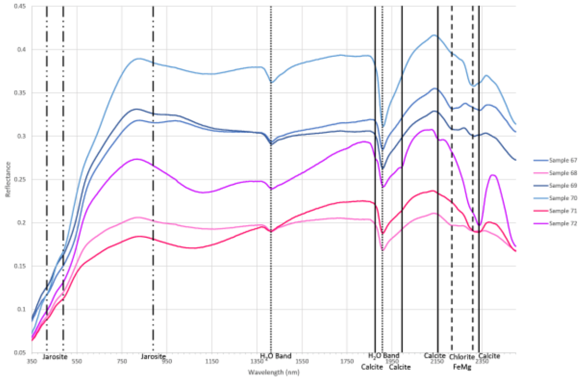

Fig. 3: Averaged VNIR spectra from each of the 6 samples collected at DCD. The sample numbers correspond with the locations depicted in Fig. 2.

Sample 72 (the xenolith sample with the crystal pockets) has a calcite signature around 1085, 1095, and 2015 nm wavelength. Both Samples 71 and 72 have the calcite signature at approximately the 2310 nm wavelength; although the signature in Sample 72's is more prominent. This is consistent with hand sample analyses as Sample 72 was almost entirely crystals, while Sample 71 had crystals in it, but only made up a moderate percentage of the sample.

Samples 67 and 69 have the doublet signature at ~420 and 485 nm, which is indicative of jarosite. Sample 70, the contact rock on the other side of the arch, also has a double dip, but it is not as prominent. Both Samples 67 and 69 have a jarosite signature at 880 nm. Sample 70 has a dip but it is shifted to the right.

Samples 67, 69, 70, and maybe 68 have the doublet dip signature of chlorite FeMg at approximately 2225 and 2310 nm.

Ongoing in-depth analysis of the spectra will help constrain how the intrusion affected mineral assemblages. Combining the spectral results with detailed mineralogy from XRD will enable us to constrain conditions of alteration and any potentially hydrothermal system. As Robbers Roost produced a likely hydrothermal system, we will also compare our results with those of [14, 15] to constrain similarities and differences in the system. The Entrada at our location is more earthy compared with it being more porous at Robbers Roost, which may affect hydrothermal activity. Finally, since we have chosen Mars analog instrumentation, we will use these results to constrain why such systems are difficult to detect on Mars and if there are key mineral assemblages to look for to find such systems.

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